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Published in:
Energy Policy

Publication date:
2005

[Link to publication in Tilburg University Research Portal](#)

Citation for published version (APA):

Arkesteijn, K., & Oerlemans, L. A. G. (2005). The early adoption of green power by Dutch households. An empirical exploration of factors influencing the early adoption of green electricity for domestic purposes. *Energy Policy*, 33(2), 183-196.

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The early adoption of green power by Dutch households An empirical exploration of factors influencing the early adoption of green electricity for domestic purposes

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Abstract

The results of this study provide empirical insight into factors influencing the early adoption of green electricity by Dutch residential users. Earlier research revealed that early adoption is closely related to social visibility, which is lacking in the case of green power. This raises the question of which factors influence adoption in the absence of visibility. The contributions of this study are threefold. First, we used a theoretical perspective in which a cognitive approach was combined with an economic approach leading to a more comprehensive framework. Second, the empirical focus on residential users of renewable resources is relatively new. Third, the results of our analyses provide insights into factors influencing early (non-)adoption, knowledge which could be valuable to market actors and governments stimulating the adoption of sustainable consumer products. For our theoretical framework, we distinguished three sets of independent variables: factors related to (1) the technical system, (2) individuals, and (3) economic issues. Data collection took place among households just 1 month before the liberalisation of the Dutch green electricity market, creating a unique database of residential (non-)users. Our results show that the proposed extended model is more powerful than partial models. Moreover, our findings suggest that cognitive and economic intentional variables, as well as variables indicating basic knowledge and actual environmental behaviour in the past, are strong predictors of the probability of adoption. The paper closes with research-based recommendations for practitioners.

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Keywords: Green electricity; Adoption; Households; Logistic regression

1. Introduction

In this study, we conducted a theory-based empirical exploration of factors influencing the early adoption of green power by households on the Dutch electricity market. Its main contribution lies in the combination of a theoretical model rooted in the cognitive approach with an economic model applied to the adoption of green power by residential users.

Market research (Intomart, 1999; Datamonitor, 2000) indicates that there is a large potential market for green

energy in Europe in general and in the Netherlands in particular. Some researchers (e.g., Bisschop et al., 2000) estimated that green electricity had a potential share of about 20% in the Dutch consumer market. Notwithstanding these estimates, at the time this study was conducted,¹ the actual situation on the Dutch electricity market for households was still far removed from this percentage. The total number of Dutch households on the market is about 7 million with a demand of 21,000 GWh (i.e., about 22% of total electricity demand). About 455 GWh is provided in the form of green power, which is about 2% of total GWh demand (Platform Versnelling Energieliberatisering, cited by

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¹ This study was conducted in June 2001, about 1 month before the market for green power in the Netherlands was liberalised, giving end-users the possibility of choosing freely their provider of green electricity.

Arkesteijn, 2001). In absolute numbers, at the end of 2000, an estimated 236,000 households used green power (Reijnders, 2002).² The above figures show that the Dutch green electricity market consisted mainly of early adopters at that point in time.

The investigation of the early adoption of renewable resources like green electricity by consumers is interesting owing to two important developments (Fuchs and Arentsen, 2002). On the one hand, liberalisation, deregulation, and privatisation have radically changed the structure and the organisation of energy markets in several countries. On the other hand, the energy policies of governments as well as the environmental concerns of users in these countries resulted in a growing focus on sustainability. Combined, these developments give end-use customers the new possibility of substituting 'green' for 'grey' power, and thus give rise to the development of a green power market.

However, switching from grey to green is not as straightforward as one might think. Households have to consider a large number of issues possibly influencing their decision. Households are faced with governmental regulations stimulating the purchase of green power, or may wish to express their personal responsibility for the environment. At the same time, owing to the fact that environmentally friendly products often have positive external economic effects that cannot be appropriated by individual parties, households may be aware of the free-rider behaviour of other consumers, which could hamper adoption. Moreover, earlier research (Fisher and Price, 1992) revealed that adoption is closely related to social and product visibility, because this enables early adopters to consolidate their social position or enables (new) adopters to feel close to a superordinate group. A clear product feature of green electricity is its invisibility, which raises the question of which factors influence adoption in the absence of clear visibility. It was therefore the aim of this study to provide empirical insight into factors influencing the early adoption of green electricity.

This study contributes to the growing body of literature on the adoption of innovations in three ways. Theoretical models used in adoption studies are strongly rooted in (social) psychology. One important group of models comprises the so-called intention models (Swanson, 1974). Fishbein and Ajzen (1975) theory of reasoned action is a well-researched intention model that has proven successful in predicting and explaining behaviour across a wide variety of domains such as computer (Davis et al., 1989; Szajna, 1996), agricultural (Lynne et al.,

1995), and medical technologies (Aubert and Hamel, 2001). According to this theory, a person's performance of a specified behaviour is determined by his or her behavioural intention to perform the behaviour, while the latter is jointly dependent on the person's attitude and subjective norm concerning the behaviour in question. A second group of theoretical models is also widely used and is strongly inspired by Rogers (1995). In this sequential model, adopters have to go through a number of steps. Since a potential adopter is confronted with a relatively unknown new product or service, at every step of the adoption process, decisions have to be made under conditions of uncertainty. To reduce these uncertainties, potential adopters collect and process information that reaches them through a variety of communication channels. In comparison with intention models, these models take a more information-seeking and processing approach to adoption.

Both groups of models emphasise the cognitive aspects of adoption processes, but underemphasise the explicit influence of economic variables, and the role of trust in the adoption process. The non-visibility of green electricity makes it impossible to gain social status by using green electricity and makes households dependent on the trustworthiness of the suppliers of green electricity. Since consumers often have to pay a premium for the supply of green power,³ perceptions of prices and price acceptance seem to be important economic concepts, which probably influence their decisions. Trust in the supplier of green electricity can function as a mechanism for uncertainty reduction and can be a substitute for possible lack of knowledge of or information on product or market characteristics. Therefore, the first, theoretical, contribution of this study lies in the use of a model in which different theoretical approaches (i.e., cognitive and economic approaches) were combined in one framework aiming at the empirical exploration of factors influencing the early (non-)adoption of green power. When combined, this resulted in a more interesting and complete theoretical approach.

Although there is a substantial literature concerning issues related to the introduction and liberalisation of green electricity as a part of the reorganisation process of the electricity sector in Europe and the USA, empirical evidence concerning factors influencing the decision to adopt green electricity of residential users is nearly absent, probably owing to the fact that there is only a limited number of years of experience and evidence to rely upon. Most authors seem to focus on energy policy issues related to the organisation of the

² The GWh figures refer to the situation at the end of 1999, while the household figures were measured at the end of 2000. After the opening of the green power market on July 1, 2001, the number of users increased significantly. On August 1, 2001, nearly 325,000 users were counted (Reijnders, 2002), representing more than a doubling of the green electricity market.

³ As will be explained later, we have an interesting empirical case, because in this case, the actual prices of green power do not differ from the prices of 'grey' power. In other words, we were able to determine the pure effect of price perceptions on adoption.

market, such as green certificates (Morthorst, 2000; Voogt et al., 2000), green power marketing (Wiser, 1998), market organisation and regulation (Arentsen and Künneke, 1996), and possible mechanisms to enhance the market penetration of renewable resources (Fuchs and Arentsen, 2002). As far as empirical research is concerned, the focus is mainly on demand-side subjects like willingness to pay for green electricity (Roe et al., 2001) or more general topics in the field of the attitudes towards and the adoption of environmentally friendly products by consumers (Derksen and Gartrell, 1993; Lynne et al., 1995; Bhate and Lawler, 1997; Minton and Rose, 1997). To the extent that the adoption of green power is researched empirically, the focus is on non-residential users (see e.g., Wiser et al., 2001). Therefore, the second contribution of our study lies in the empirical exploration of factors influencing residential users to adopt green power, which, to our knowledge is an unexplored area.

From a practical point of view, understanding the reasons why consumers purchase green electricity is of importance to policymakers interested in stimulating demand for green power, and to suppliers of the product trying to maintain or increase their market share in the household electricity market. The empirical results presented in this paper are especially suitable for this purpose, since our data were collected from adopters and non-adopters of green power in June 2001, just 1 month before the liberalisation of the Dutch green electricity market. At that point in time, consumers were not yet the object of massive marketing activities of (new) suppliers in the market, but conscious of the fact that they would be confronted with new possibilities. As a result, most consumers were relatively unfamiliar with the precise characteristics of the market and the product. In other words, consumers were forced to evaluate green power while having little information. In such a case, (mis-)perceptions of the product play an important role in the decision-making process. Our data and analyses provide insights into these perceptions and their influence on adoption, which could be valuable to policymakers and other market actors stimulating the adoption of renewable resources. Here lies the third contribution of this study.

The remainder of the paper is structured as follows. In the next section, we describe how the theoretical framework was developed and a number of testable hypotheses were formulated. In the section that follows, we report on the research methodology used in this study. We discuss the survey method used, the measurement of the variables derived from our theoretical framework, and the statistical methods that were applied. In the following section, we report on our empirical results. The paper ends with brief summary remarks and a discussion on the theoretical and practical relevance of our findings.

2. Theoretical framework and hypotheses

The adoption of green power by residential users is an interesting research topic. It seems that the conditions for the adoption of green products in general (e.g., hydrogen-fuelled cars, health goods, recycled products) and green power in particular by consumers are favourable. Firstly, the environmental advantages of the production and use of green electricity seem to be clear. Emissions such as nitrogen oxide, sulphur oxide, and carbon dioxide are reduced considerably and the production and use of green electricity contributes to diminishing the green house effect, the effects of acid rain, and the use of valuable but scarce fossil resources. Secondly, concern for the environment has become almost a cultural norm in most western countries, probably setting the 'stage' for the introduction of green products. Pro-environmental attitudes are considered socially acceptable and desirable, although it is not clear whether these have much intrinsic value (Derksen and Gartrell, 1993, p. 434). Several surveys have shown that the distributions of environmental concern are, on average, highly skewed, with as many as 90% of respondents in a given sample expressing high levels of environmental concern (Derksen, 1990; Minton and Rose, 1997). Comparable findings have been found for levels of concern for related environmental issues, such as acid rain, air pollution, and holes in the ozone layer (Bhate and Lawler, 1997). To some extent, this awareness has been displayed in the conscious efforts of consumers to buy products that do not harm the environment, or the donation of funds to charities involved in its protection (Martin and Simintiras, 1995; Minton and Rose, 1997), both opening doors to niche markets for businesses. Thirdly, the Dutch government has implemented policies stimulating the use of green electricity, another favourable condition for the adoption of green power. As a result of EU policy, the Netherlands has to ensure that in 2010 about 10% of the overall energy supply will be produced in a sustainable way (Reijnders, 2002). Through the liberalisation of the green electricity market and by offering relatively generous fiscal incentives,⁴ the Dutch government tries to stimulate the demand for green power and to achieve this goal.

Although conditions seem to be relatively favourable for the adoption of green power by households, several

⁴In January 2001, a differential ecotax was introduced exempting households buying green electricity from paying ecotax for the kWh they use. As a result, the price of green electricity generally equals the price of grey electricity in the Netherlands. Moreover, a certification system was put in place to guarantee that the green electricity sold to consumers is indeed produced in a sustainable way. Finally, by subsidising the purchase of small-scale production equipment (e.g., solar panels) the government tries to stimulate the production of sustainable energy by households.

arguments can be found in the literature, which indicate that, owing to the characteristics of the product and its market adoption could be inhibited.

Firstly, as [Wiser \(1998\)](#) argues, to a certain extent, green power can be labelled as a public good. Although the commodity supply of electricity produced by a renewable energy source and its distribution to a customer is a private good, at the same time, green power provides net public benefits, making it partially a public good.⁵ Traditional economic theory suggests that, because the benefits of a public good cannot be captured fully by purchasing users, actors have a strong incentive not to contribute but to ‘free-ride’ and profit from the benefits of the public good while not paying for it. These characteristics could hamper the early adoption of green power by households.

Secondly, writings on adoption ([Veblen, 1899](#); [Fisher and Price, 1992](#)) state that the early adoption of new products is often motivated by social benefits. General theory states that actors in superordinate social positions choose new products as a means of creating, sustaining, and communicating social differentiation. Subordinates display imitation behaviour in order to feel close to superordinates and improve their social position. The social and communicational value of the early adoption of a new product is highly dependent on its social visibility and the possibility of associating it with superordinate groups. On the one hand, visibility is necessary so that others are conscious of the behaviour and have the possibility of decoding its meaning. On the other hand, early adoption constitutes the social desirability of the behaviour. As [Fisher and Price \(1992, p. 477\)](#) state, ‘the adoption is an implied endorsement that positions the new product as a symbol of group affiliation’. Research efforts on early adoption have focused on highly eye-catching and stylised new products such as new clothing fashions ([Midgley, 1983](#)), automobiles ([Blumberg, 1974](#)), new personal computers ([Kim et al., 2001](#)), and digital cable ([Kang, 2002](#)). Within this context, the adoption of green electricity is an interesting case. Owing to its product characteristics, the social visibility of the adoption and even the overall visibility of the product are quite low. Green and grey electricity do not differ in a physical sense, while the product cannot be considered an appealing product since it is a basic good in most western societies. Hence, the question of which factors influence the early adoption of green electricity in the absence of a high level of social visibility remains unanswered.

⁵Wiser (1998, 2001) mentions two points: (a) because renewable resources cause less environmental damage per unit of energy output, net environmental and societal benefits are provided; and (b) the knowledge that is created with the development of renewable energy systems cannot be easily and fully appropriated by private actors (see also [Teece, 1986](#)). These advantages benefit all customers, irrespective of individual participation in green power projects.

Thirdly, in the previous market situation, consumers were used to receiving electricity from monopolistic providers, some of which offered their customers green electricity.⁶ By liberalising the residential market for green electricity only, the Dutch Government wanted to stimulate providers to supply green electricity. In a liberalised market environment, consumers’ positions change substantially ([Fuchs and Arentsen, 2002](#)). They now have the opportunity to switch to other suppliers. These new possibilities may create several informational problems that can hamper adoption. For example, where to find reliable and relevant information about prices and suppliers? In the early phase of development, the level of market transparency is relatively low and early users are inexperienced, thus creating uncertainties for their adoption decision. Furthermore, how do early users learn about the features of a new product like green electricity? Recent research ([Moreau et al., 2001](#); [Wood and Lynch, 2002](#)) indicates that prior knowledge of product categories that are perceived as related to the new product is used by users to create (in-)correct representations of the features and use of a new product. Such representations can influence the adoption decision. This implies that actors who already have knowledge of different sources of sustainable power are probably more willing to adopt.

These contrasting considerations enabled us to formulate a research model and specify hypotheses with the aim of exploring the early adoption of green electricity empirically. The remaining part of this section deals with the theoretical underpinnings of our research model.

We defined innovation as ‘any idea, practice, or material artefact perceived to be new by the relevant unit of adoption’ ([Zaltman et al., 1973](#)). Similarly, [Rogers and Shoemaker \(1971\)](#) delimited innovation as ‘an idea, practice, or object perceived as new by the individual’. The common denominator in both definitions is that what matters is whether the innovation is new to the potential adopter. Whether it is new in the objective meaning of the word is not important, as long as the adopting unit regards it as new. As soon as an individual perceives something as new, a situation is created in which actors have to evaluate, learn, process information, or take some other actions in which uncertainty and bounded rationality play their roles.

Following [Aubert and Hamel \(2001\)](#), the first building blocks of our research model were two groups of adoption factors: adoption factors linked to a technical system and adoption factors related to individuals. Many authors take these factors, which were already introduced by Rogers, as their starting point and then complement them with others. We followed the same

⁶Before January 2001, the price of green electricity was higher than grey electricity.

Table 1
Variables influencing adoption of green power by households

Variables	Description	Anticipated effect hypothesised
Perception of ease of switching and use	Perception of the ease with which a switch can be made from grey to green power	H1: Increase probability of adoption
Perception of probability of power failures	The perceived chance of power failures when using green power in comparison to the usage of conventional power	H2: Decrease probability of adoption
Trust in green electricity supplier	The level of trust individuals place in green power suppliers with regard to the generation and additional investments in green power plants	H3: Increase probability of adoption
Responsibility for the environment	Attitude of individuals towards environmental responsibilities	H4: Increase probability of adoption
Perception of relative advantages	The level to which green power is perceived as superior to grey power by individuals	H5: Increase probability of adoption
Basic knowledge	Level of basic knowledge individuals have about related ways to generate green power	H6: Increase probability of adoption
Perceived importance of used communication networks	Quotient of perceived importance of information received by interpersonal channels and mass media channels	H7: Increase probability of adoption
Actual displayed environmental behaviour	The number of environmental associations individuals are subscribed to	H8: Increase probability of adoption
Willingness to pay	Willingness of individuals to pay a premium for green power	H9: Increase probability of adoption
Perception of price green electricity	Perception of the price of green power in comparison to the price of conventional power	H10: Decrease probability of adoption
Net income	Net disposable household income	H11a: Increase probability of adoption H11b: No effect

approach. The factors and the related hypotheses are presented in Table 1.

2.1. Adoption factors related to the technical system

This group of factors encompasses characteristics of the technical system that influence the individual adoption decision. These factors are linked to how the system is designed, perceived, and used in the final user environment.

The first factor in this group is system complexity, referring to the difficulties individuals can encounter in understanding and using an innovation. Within the context of the adoption of green power, this factor can be refined to ‘ease of switching and use’ (see also: Moore and Benbasat, 1991; Seddon and Kiew, 1994), which relates to the perceived ease of switching from conventional to green power.

- H1 The more users think green power is difficult to acquire and integrate into their daily practices, the lower the probability of adoption will be.

The second factor included in the technical system group is system reliability. Users expect a continuous supply of power from their electricity companies. The technical system that supported the production and distribution of grey electricity guaranteed high levels of reliability. Teubal (1979) stated that users are often uncertain about the product quality characteristics of

innovations. In the case of green power, users may think that the production and distribution of green power is more susceptible to the occurrence of power failures, e.g., because they believe that using sustainable sources such as wind or solar energy are too dependent on weather conditions. Consequently, power supply may be interrupted and thus more unreliable.

- H2 The more users think the supply of green power is characterised by higher probabilities of system breakdowns or power cuts, the lower the probability of adoption will be.

Owing to the low visibility of the product and the low level of market transparency, potential adopters are faced with uncertainties. After all, if an actor wants to adopt green power, he expects that this electricity is generated in a sustainable way and that the producer invests financial resources in sustainable production equipment.⁷ The actor cannot be completely sure, however, that the electricity he or she buys is really

⁷At the time this research was conducted, there was an ongoing public discussion in the Netherlands about the delineation of green electricity. The official definition included the production of green electricity with biomass, using, among other things, pig and chicken manure as fuel. Some felt that biomass should be excluded because electricity generated in this way was not really ‘green’. Moreover, it was reported in newspapers that suppliers did not invest enough in production equipment and imported green electricity from abroad. As a result, there were some doubts about the authenticity of the imported electricity, since no international quality label existed.

green since the product cannot be physically distinguished from conventional power and suppliers use different means to generate green power. High levels of trust in suppliers can counteract these uncertainties. The argument runs as follows (Numan, 1998). If a decision-making unit trusts something (product, brand name, producer), a high level of external complexity⁸ is transformed into a low level of internal complexity. Trust leads to the expectation (without certainty) of an actor that only a limited number of events are possible. As a result of trust, uncertainty and risk perceptions are reduced, and the actor has a higher sense of control.

- H3 The more users trust green power suppliers, the higher the probability of adoption will be.

2.2. Adoption factors related to individuals

The actor's perception of his own responsibility for the environment is the first factor related to the individual. It is defined as the value judgement actors have of environmental responsibility. Several researchers (Ellen et al., 1991; Ellen, 1994; Minton and Rose, 1997) found that a generally positive attitude toward improving the environment was a significant predictor of purchasing environmentally safe products, recycling, and contributing money to environmental pressure groups. On the one hand, actors considering the adoption of green power may be influenced by their feelings of moral responsibility to contribute to the improvement of the environment or to accept the responsibility of the present generation for the living conditions of future generations, which would influence the possibility of adoption in a positive way. On the other hand, actors may think that other actors like governments or large firms are accountable for present energy and environmental problems. As a result, users do not feel intrinsically responsible for the environment, which probably decreases their propensity to adopt green power. Therefore, Hypothesis 4 was as follows:

- H4 The more actors feel responsible for the environment, the higher the probability of adoption of green power will be.

Rogers (1995) already suggested that the perceived relative advantages of an innovation might be one of the important factors explaining adoption. Relative advantage refers to the extent to which an innovation is perceived as superior to the technology or product it is replacing. The advantages of green power perceived by individuals may be the positive effects its production

and use have on the environment in general or the lower emission levels of green house gases, in particular, in comparison with the production and use of grey power

- H5 The higher the perceived relative advantages of an innovation, the greater the likelihood that the innovation will be adopted.

As was explained in a previous paragraph, consumers often use prior knowledge of comparable product categories to learn about new products. Prior knowledge is defined as the amount of domain-specific knowledge acquired through experience or training (Spence and Brucks, 1997). Following Rogers (1995), we argue that the decision-making process leading to adoption starts when an actor is exposed to, becomes familiar with, or has an idea about the functioning of an innovation. In the case of the adoption of green power, this implies that an actor has to know that green electricity is an existing product and that the way it is produced differs from the way in which conventional electricity is generated. More knowledgeable actors are assumed to be more willing to adopt. Therefore, Hypothesis 6 was

- H6 The more users have prior knowledge about the production and use of sustainable produced power, the greater the likelihood that they will adopt green power.

In Rogers' adoption models, actors use communication networks to receive or acquire information, which can reduce their uncertainty about an innovation and help them to make their adoption decision. Information can reach the actor through a variety of sources and channels. Following Valente (1993), two main processes of diffusion of information are discerned: internal and external influence. Internal influence is diffusion by interpersonal communication through word of mouth or through social networks. External influence is diffusion by information sources external to the interpersonal interaction between individuals. Examples are mass media, journals, pamphlets, and fliers. The effects of both forms of influence in the adoption process are different, according to Rogers. External influence channels play their most important role on the knowledge function, while the effects of internal influence channels are more important on the persuasion and decision functions. Furthermore, not only the use of a specific channel of communication is relevant, but also the perception of it, because it signals how the actor evaluates the received information. Therefore, we hypothesised, that

- H7 The more actors attribute importance to information received from internal influence channels as compared to external influence

⁸A high level of external complexity is indicated by lack of knowledge and the perceived high complexity of an innovation.

channels, the higher the probability that they will adopt green power.

The ways in which people made conscious efforts in the past to protect the environment may be a predictor of early adoption behaviour, because in these cases, intentions are transformed into actual behaviour (Derksen, 1990; Minton and Rose, 1997). The more initiatives people already take to show their commitment towards the environment, the more likely it may be that they will adopt green electricity. Therefore, Hypotheses 8 was

- H8 The more consumers showed actual environmental behaviour in the past, the higher the probability that they will adopt green power.

2.3. *Adoption factors linked to economic issues*

Most adoption models rooted in the cognitive approach tend to emphasise beliefs, norms, perceptions, and attitudes as the factors shaping adoption. Although we recognise the importance of these variables in decision-making processes regarding adoption, it is also our view that, especially in the case of environmentally friendly products like green power, economic issues cannot be neglected. Despite their many beneficial attributes and impressive cost reductions, most renewable energy applications are still more expensive than competing sources of electricity generation, or people think they are more expensive. Potential adopters of green power have to overcome these (perceived) economic market barriers that probably decrease the likelihood of adoption. Therefore, we added three economic variables to our theoretical framework, in this way extending cognitive notions of intentions with economic ones.

The first factor in this group was willingness to pay, referring to the propensity of individuals to pay an extra amount of money for the purchase of green power. Using conjoint analysis, Roe et al. (2001) showed that several different demographic segments in the US market are willing to pay more for environmentally friendly electricity generation methods. Bhate and Lawler (1997) found the same result in their study of factors influencing the adoption of environmentally friendly products. We assumed that a comparable relationship exists between willingness to pay and the adoption of green power.

- H9 The more actors are willing to pay a premium for the purchase of green power, the greater the likelihood of its adoption will be.

We also included the perception of price in our theoretical framework. Price perception was defined as

the estimated price difference between grey and green power. If individuals think there is a large difference between the two, i.e., they perceive green power as (very) expensive in comparison with grey power; it is logical to assume that this will decrease the probability of adoption. We assumed that

- H10 Higher price perceptions decrease the likelihood of adopting green electricity.

The last economic variable included in our model was level of income. One could assume that there is a positive relationship between level of income and the likelihood of adoption of green power. Since income is a proxy of wealth, one might expect that early adopters of green power often belong to the higher-income classes, who can afford more expensive products or behaviour. Empirical evidence of the relationship between income level and environmentally friendly behaviour is not conclusive, however. Gartrell et al. (1973) found a positive and linear relationship between income and innovative behaviour among farmers, whereas Derksen and Gartrell (1993) found no statistically significant relationship between income and recycling behaviour. Two competing hypotheses were derived from above

- H11a Higher levels of income increase the likelihood of adoption of green electricity.
H11b Higher-income levels do not impact on the likelihood of adoption of green electricity.

In the next section, we discuss some methodological issues related to the empirical investigation of the theoretical framework described in this section.

3. *Research methodology*

3.1. *Survey procedures and sample*

To investigate our hypotheses empirically, a telephone survey was conducted among adopters and non-adopters of green electricity in a major city in the Netherlands. The city, located in a Dutch province in the southern part of the country, is one of the economic motors of the province. The city covers an area of 8522 hectares with an average of 652 inhabitants per square kilometre, which makes it a typical urban area. In June 2001, a total of 37,223 households had an electricity metre, of which 94% used 'grey' electricity and 6% green electricity.⁹

A stratified disproportional random sample was used. The sample consisted of two strata: green electricity

⁹ By that time, the regional electricity distributor had offered green electricity to its customers (residents and non-residents) for 2 years.

users and non-green electricity users. A total of 250 households from each stratum were chosen at random from the customer database of a regional electricity distribution company, which supplied green electricity throughout the Netherlands. The combined sample was not a reflection of the percentage of green electricity adopters in the total population.

A telephone survey was chosen as the most suitable mode of data collection. Initially, all 500 households received a letter announcing a pending ‘electricity use’ survey without mentioning green electricity as the specific field of interest.

The survey was started just before the liberalisation of the green electricity market in June 2001. A total of 95 green electricity adopters and 110 non-green electricity adopters were approached by phone,¹⁰ generating data for 115 respondents, of whom 55 were green electricity adopters and 60 were non-green electricity adopters. The response rates were 58% and 55%, respectively. The green electricity adopters can be categorised as early adopters because more than 65% of the respondents subscribed to green electricity more than 1 year before the start of the survey.

To determine whether the respondents were representative of the Dutch population, a comparison of age, income groups, and household size was undertaken using data from the 2000 Census (Central Bureau of Statistics). The results appeared to contain external validity and, therefore, the respondents were representative of the entire Dutch population.

3.2. *Measurement of variables*

The questionnaire was aimed at evaluating the adoption behaviour of residential users and non-users of green electricity. In the previous section, we defined a theoretical framework including factors that possibly explain the behaviour of households in adopting green electricity. Most of these variables were measured in a straightforward way, which is explained in Table 2. The measurement of the variables ‘Individual’s Perception of own Responsibility for the Environment’, ‘Perception of Ease of Switching and Use’, ‘Perception of Relative Advantages’, the perceived importance of the used communication networks, and ‘Level of Trust in Green Electricity Supplier’ needs a more elaborate explanation.

The dependent variable was measured using the question ‘Do you use green electricity’ and was a dummy coded variable (yes = 1; no = 0).

Following from Section 2, the independent variables were divided into three sub-categories; three variables related to the technical system, five variables related to individuals, and three variables related to economic

issues. The first technical system variable was the perception of ease of use. ‘Perception of Ease of Use’ refers to the extent to which respondents agreed with the following items: (1) The switch to green electricity causes a great deal of trouble; (2) Switching electricity suppliers is definitely necessary in order to use green electricity.¹¹ The different items were measured using a 4-point Likert scale (1 = fully agree; 2 = agree; 3 = disagree; 4 = totally disagree). Factor analysis showed significant correlation within this set of items¹² and resulted in a one-factor solution. The factor scores were saved and labelled as the new variable ‘Perception of Ease of Switching and Use’. A higher value of the variable stands for a higher perceived ease of use of green electricity.

The second technical system variable was ‘The Perception of the Probability of Power Failures’. Households were asked to indicate what the probability of a system breakdown or a power failure was when using green electricity in comparison with the chances of a power breakdown when using conventional electricity. Scores could vary between 0% and 100%. Higher scores indicate a higher estimated probability of power failures when using green electricity in comparison with using grey power.

The ‘Level of Trust in Green Electricity Supplier’ was measured using two items. On the one hand, respondents were asked to indicate to what extent they trusted the green electricity supplier to really supply renewable electricity generated in a sustainable way. On the other hand, respondents were asked to indicate to what extent they trusted the green electricity supplier to invest extra money in the construction of sustainable electricity generators. These two items were measured using a 5-point Likert scale (1 = no trust at all, 5 = much trust). Factor analysis¹³ resulted in a one-factor solution. Higher values of this variable indicate a higher level of trust in the green electricity supplier.

The second group of variables was related to individuals. The independent variable ‘Individual’s Perception of own Responsibility for the Environment’ was the result of a factor analysis¹⁴ using three items, which produced a one-factor solution. Respondents were asked to what extent they agreed with the following propositions: (1) I am obliged to use sustainable energy for future generations (1 = completely disagree, 5 = fully

¹¹ Initially, three items were included in the factor analysis. In subsequent analyses, it turned out that one of the items caused major multicollinearity problems and was, therefore, excluded from further analyses.

¹² KMO = 0.500; Barlett’s Test of Sphericity $p = 0.000$; cumulative percentage of variance explained = 75.19%.

¹³ KMO = 0.500; Barlett’s Test of Sphericity $p = 0.000$; cumulative percentage of variance explained = 83.92%.

¹⁴ KMO = 0.541; Barlett’s Test of Sphericity $p = 0.000$; cumulative percentage of variance explained = 53.14%.

¹⁰ It was decided to use a minimum of 55 respondents per stratum, balancing time constraints and statistical relevance.

Table 2
List of variables used in the analyses

Variables	Indicators
Adoption of green electricity (dependent variable)	Adoption of green electricity (dummy; 1 = yes, 0 = no)
Perception of ease of switching and use	Perceived ease of switching to green electricity by respondents (not easy at all = 1, very easy = 4)
Perception of probability of power failures	The perceived chance of a power cut when using green electricity in comparison to the chance of a power breakdown when using conventional electricity (0–100%)
Level of trust in green electricity supplier	The level of trust of respondents in electricity suppliers with regard to the generation and extra investment in green electricity (very low = 1, very high = 5)
Attitude towards environment	Attitude of the respondents towards environmental responsibility (very low = 1, very high = 5)
Perception of relative advantages	Perceived environmental benefits of using green electricity (very low = 1, very high = 5)
Knowledge of renewable energy sources	Knowledge of different ways to generate green electricity (dummy; 1 = yes, 0 = no)
Perception of importance of used communication networks	Quotient of perceived importance of received green electricity information by internal influence channels (through word of mouth and/or social network) and external influence channels (e.g. mass media, journals) (internal influence channels more important > 1; external influence channels more important < 1)
Actual displayed environmental behaviour	The number of subscriptions to environmental associations
Perception of price green electricity	Price perception of green electricity in comparison to conventional electricity (estimated difference in Dutch guilders)
Willingness to pay	Willingness to pay an extra amount of money for green electricity per month (in Dutch guilders)
Net income	Disposable net income of all members of a household per month (<Euro 1022; Euro 1022–1590; Euro 1590–2498 and > Euro 2498)

agree); (2) As long as industry does not take responsibility for the deterioration of the quality of the environment, I will not do anything (1 = fully agree, 5 = completely disagree); (3) The Dutch government should make the use of renewable electricity compulsory (1 = completely disagree, 5 = fully agree). The higher the value, the more positive the attitude towards the environment is.

‘Perception of Relative Advantages’, another independent variable in this category, was the result of factor analysis¹⁵ using two items: (1) If I use green electricity, I will contribute to decreasing the green house effect (5-point Likert scale; 1 = totally disagree to 5 = fully agree); (2) The use of green electricity does not damage the environment as much as is often suggested (5-point Likert scale; 1 = fully agree to 5 = totally disagree). A one-factor solution resulted, the factor scores of which were saved as a variable. The higher the value of this variable the higher the perception of Relative Advantages is.

To measure the level of existing knowledge of renewable energy, households were asked to indicate how many different ways of generating green electricity they knew. Where households spontaneously answered electricity from solar, wind, water, or geothermal energy, and/or biomass, the value 1 was assigned and 0 was assigned in all other cases.

Another variable related to individuals was ‘Actual Displayed Environmental Behaviour’, which was

measured using the number of memberships of environmental associations. Households could indicate to which regional, national, or international wildlife, flora and/or fauna organisation (such as WWF, Natuurmonumenten, Green Peace, etc.) they subscribed. A higher number of different memberships indicates that stronger actual environmental behaviour was displayed in the past.

The last independent variable in this category was ‘the perceived importance of the communication networks used’. We asked households whether they had recently received information concerning green electricity and how important they perceived this information to be (1 = not important at all/no information received to 6 = very important). Respondents could mention a maximum of three different information sources and indicate their importance. The information sources mentioned were later divided into two different groups: internal influence channels (information received through interpersonal channels, i.e., family, friends, colleagues) and external influence channels (information received through non-personal channels). Scores on the items related to both groups were added to the total scores of both. Next, the internal influence score was divided by the external influence score, resulting in the variable ‘the perceived importance of the communication networks used’. The higher the value of this variable, the more important consumers perceived the information received through internal influence channels.

Lastly, the three economic variables were measured. Firstly, households were asked (to estimate) how much

¹⁵ KMO = 0.500; Barlett’s Test of Sphericity $p = 0.000$; cumulative percentage of variance explained = 67.52%.

money (in Dutch guilders) they thought they would have to pay for green electricity in comparison with conventional electricity if conventional electricity costs 100 Dutch guilders (€45) per month. The higher the estimated difference in Dutch guilders, the higher the perceived price of green electricity is. Next, households were asked to express their willingness to pay an extra amount of money for green electricity (in Dutch guilders per month). There was also the possibility to indicate that no extra amount of money should be paid. The higher the expressed amount of money indicated by the respondents, the higher the willingness to pay extra for green electricity is.

The last variable in our model was the net income of households. The net income was measured by asking households to indicate what the disposable income of all the members of the household per month was: (1) less than €1022, (2) between €1022 and 1590, (3) between €1590 and 2498, or (4) more than €2498 (original dimension was in Dutch guilders).

3.3. Research design

In order to test the relative importance of the independent variables with regard to the adoption of green electricity, the model was analysed using logistic regression analysis with the backward stepwise likelihood ratio method.¹⁶ All variables were entered in the first step and the variable with the smallest partial correlation with the dependent variable was removed in the following step, based on removal criteria ($p > 0.05$). All models were tested for multicollinearity using a Tolerance statistic.¹⁷ We concluded that no multicollinearity¹⁸ problem existed, because tolerance statistics ranged from 0.512 to 0.855, which is well above 0.2.

In linear regression, the interpretation of the beta coefficient (β) is straightforward. It shows the amount of change in the dependent variable for a one-unit change in the independent variable. The interpretation of the beta coefficient in a logistic regression model is different. A logistic model can be written in terms of the odds of an event occurring. These odds are defined as the ratio of the probability that an event will occur against the

probability it will not. In Table 3, this is expressed by the $\text{Exp}(B)$ coefficients.¹⁹

There are various ways to assess whether or not the model fits the data. Firstly, the model chi-square was used. A significance level of the model chi-square value less than 0.05 indicates that the model with the included variables fits the data better than a model without these variables. Secondly, we used the Hosmer and Lemeshow goodness-of-fit test, which tests whether there are statistical significant differences between observed probabilities and those predicted by the model. If the Hosmer and Lemeshow test value is small and its level of significance is large ($p > 0.05$), one can conclude that the model fits the data.

Thirdly, the value of the Nagelkerke R square was used. This indicator is comparable with R square in linear regression analysis. If Nagelkerke's R square is 0, the independent variables have no predictive value. If it equals 1, the independent variables are perfect predictors.

We estimated five models. In the first three models, the influence of the technical system variables, the individual variables, and economic variables, respectively, on the likelihood of adoption were regressed separately. In this way, we were able to find out what the predictive power of each set of variables was. The fourth model combined the sets of technical system variables and individual variables. In the fifth model, the economic variables were added to the fourth model. These last two models were the expression of our theoretical intention to combine sets of variables derived from different theoretical perspectives and were aimed at a more comprehensive empirical exploration.

To test statistically the improvement of model four in comparison to model one, and model five in comparison to model four, we used the log-likelihood ratio test (Hosmer and Lemeshow, 2000, p. 37). This ratio test compares the $-2LL$ s of a restricted model (e.g., model 1) and an unrestricted model (model 4). The deviation of the $-2LL$ s has a chi-square distribution with n degrees of freedom, where n stands for the number of additional variables added in the unrestricted model. If a chi-square test has a level of significance of < 0.05 , the unrestricted model has a higher predictive quality than the restricted one.

4. Results

Table 3 shows the results of the logistic regression analyses.

All estimated models performed well. The tests indicating how well the models fit the data (model

¹⁶ Menard (1995) suggests using the backward stepwise method in case of an exploratory research to guard against the so-called suppressor effect.

¹⁷ To test for multicollinearity problems, we followed the suggestion of Menard (1995). We used multiple linear regression analysis with all variables of our model, using the Tolerance statistic as an indicator. $\text{Tolerance} = 1 - R_x^2$, where R_x^2 is the variance in each independent variable explained by all the other independent variables. A tolerance of less than 0.2 is a cause for concern.

¹⁸ Collinearity is a problem that arises when independent variables are intercorrelated. When perfect collinearity exists, it is impossible to obtain a unique estimate of the regression coefficients.

¹⁹ If the $\text{Exp}(B)$ value of an independent variable is > 1 , this means that the likelihood that households will adopt green electricity is increased. If $\text{Exp}(B) < 1$, this likelihood is decreased. A value equal to 1 indicates that a variable has no influence.

Table 3

Binary logistic regression analyses with the adoption of green electricity as the dependent variable and the factors influencing the adoption of green electricity among households as independent variables (in parenthesis *p*-values)

Independent variables	Model 1	Model 2	Model 3	Model 4	Model 5
<i>Technical system variables</i>					
Perception ease of switching and use	4.144 (0.002)			2.821 (0.010)	2.798 (0.032)
Perception of probability of power failures	n.s.			n.s.	n.s.
Level of trust in green electricity supplier	2.316 (0.000)			1.899 (0.046)	n.s.
<i>Individual variables</i>					
Attitude towards the environment		2.614 (0.002)		2.546 (0.016)	2.318 (0.050)
Perception of relative advantages		n.s.		n.s.	n.s.
Knowledge of renewable energy sources		4.909 (0.005)		4.508 (0.019)	5.621 (0.027)
Perceived importance of used communication networks		n.s.		n.s.	n.s.
Actual displayed environmental behaviour		3.374 (0.000)		2.657 (0.006)	2.410 (0.024)
<i>Economic variables</i>					
Net disposable income			n.s.		n.s.
Willingness to pay			1.169 (0.000)		1.161 (0.001)
Perception of price green electricity			0.927 (0.000)		0.933 (0.007)
Constant	1.026(0.918)	0.111 (0.000)	0.461 (0.044)	0.174 (0.004)	0.089 (0.007)
Model-2LL	96.590	93.591	90.499	69.109	51.215
Model chi square	39.103 (0.000)	54.658 (0.000)	53.637 (0.000)	59.289 (0.000)	71.614 (0.000)
Hosmer and Lemeshow test	12.301 (0.138)	6.158 (0.630)	14.123 (0.079)	14.806 (0.063)	8.756 (0.363)
Nagelkerke <i>R</i> square	0.439	0.533	0.537	0.630	0.739
% Correct overall	75.5%	78.5%	84.6%	80.6%	86.5%
% Correct non-adopters	76.6%	83.6%	79.3%	81.4%	85.4%
% Correct adopters	74.5%	73.1%	90.2%	80.0%	87.5%

n.s. = Not significant.

Model 1 = adoption factors related to the technical system; model 2 = adoption factors related to the individual; model 3 = adoption factors related to economic issues; model 4 = model 1 + model 2; model 5 = model 1 + model 2 + model 3.

chi-square and the Hosmer and Lemeshow test) show that this was indeed the case for all models. Nagelkerke's *R* square varied between 0.439 for the model including only technical system variables and 0.739 for the model containing all variables, which is evidence of the relatively high quality of the models. The third indicator of model performance was the percentage of correctly predicted cases. These (overall) percentages varied between 75.5% for the model containing only technical system variables and 86.5% for the total model, again showing that we had relatively powerful models.

To test the predictive value of each set of independent variables, three models were estimated (models 1 to 3). It turned out that each set had a predictive value of its own. In model 1 (technical system variables), the perception of the ease of use of green electricity and the level of trust in the supplier of green electricity increased the likelihood of adoption. If users think that green electricity is difficult to acquire and integrate into daily practices, they are less willing to adopt. Moreover, because the features of green power and its production are relatively unknown to possible users and they are not in the position to check these, they have to rely on the trustworthiness of the supplier. It seems that the less

trust users put in their suppliers, the lower the probability of adoption is. In this sense, trust acts as a mechanism to reduce uncertainty. The perception of the probability of power failure refers to system reliability and had no effect in our model. This signals that respondents' decisions whether or not to adopt green electricity are not influenced by their perceptions of system reliability. We can conclude from this result that the respondents do not evaluate the two products ('grey' and 'green') differently as to their reliability.

The second set of variables (model 2) encompassed adoption variables related to individuals. Three out of the five variables were statistically significant. Higher levels of perceived responsibility for the environment, higher levels of basic knowledge of renewable energy, and environmental behaviour displayed in the past were all found to increase the likelihood of adoption of green electricity. These findings can be interpreted as a confirmation of important parts of Rogers' adoption model. It is interesting, however, that one of the key variables in his model, the perceived relative advantages of an innovation, had no effect in our model. A possible explanation for this finding could be that most respondents were already convinced of the comparative advantages of green electricity. Because of a lack of

variation, the variable lost its predictive power. The perception of the used communication networks did not have a significant influence on the adoption of green electricity when the individual variables were taken into account. It can be concluded that individuals' perception of their own responsibility for the environment and their pre-existing knowledge of renewable energy sources have a stronger predictive power than the information network used. Owing to the fact that green electricity is a non-visible, new product on the market, general information independent of the source is necessary to get an understanding of the characteristics of the product. For the early adopters, this basic knowledge and a high level of perceived environmental responsibility is enough to make the decision to adopt the product. In model 3, economic variables related to the use of green electricity were included in the logistic regression model. The findings show that willingness to pay and price perception were both significant in the expected directions. Net disposable income had no effect at all when only economic variables were taken into account, although several researchers have found this to have a positive influence on the probability of adoption. This result requires an explanation. It can be concluded that price perception and willingness to pay are stronger economic predictors of adoption behaviour than level of income. The fact that the (price) information was scarce at the time of the research meant that most of the households perceived the price of green electricity as higher than the amount of money they were willing to pay for green electricity independent of their income levels. Moreover, owing to the non-visibility of green electricity, the argument of high-income innovators consolidating their social position is not applicable.

Model 4 combined models 1 and 2 and can be seen as a model strongly rooted in the cognitive sciences. The estimated model did not lead to new conclusions in terms of the variables included in the model. However, the addition of the variables of model 2 did increase the overall performance of the model. The log likelihood ratio test had a chi-square of 27.481 with a level of significance of <0.000 . Therefore, it can be concluded that this model, with its variables derived from the cognitive sciences, was capable of explaining the adoption of green electricity to a considerable extent.

In Section 2, we recognised the importance of the cognitive adoption models but we also argued that these models should be complemented with variables derived from economic science. This is especially of importance when analysing the adoption of green products since these tend to be (perceived as) more expensive, which could be an economic barrier to adoption. Model 5 was the empirical translation of this line of reasoning. Adding economic variables did result in a more powerful and comprehensive model, as can be concluded from the level of significance of the log-likelihood ratio test

(chi-square = 17.894; $p < 0.0000$), the percentage of correctly predicted cases (from 80.6% to 86.5%), and the strong model fit. A second interesting finding is that the influence of 'basic knowledge' was stronger in this model. This result points to the importance of pre-existing basic knowledge of green energy in general, and green electricity in particular for adoption. Thirdly, adding economic variables led to the exclusion of 'trust in green electricity supplier'. It seems that the combination of cognitive variables with economic variables counteracted the effects of a lack of trust in suppliers of green electricity. The willingness to pay more money for green electricity could be a statement in itself that early adopters have confidence in the product. Moreover, economic variables were relevant predictors of the adoption of green electricity in the 'full' model, indicating that omitting important variables from the model could give an incomplete picture of the motives for adopting an innovation.

Two important conclusions can be derived from the results of our analyses. Firstly, using a model in which adoption variables derived from the cognitive sciences were complemented with economic variables was a fruitful research strategy. It led to a more comprehensive and powerful model predicting actual adoption behaviour. Secondly, most of our hypotheses were confirmed. Notable exceptions were the perception of the probability of power failure, relative advantages, net income, the perceived importance of the communication networks used, and the level of trust in green electricity suppliers (in model 5 only). In the next section, we briefly discuss the implications of these results.

5. Discussion and conclusion

The aim of the study was to empirically explore factors influencing the likelihood of adoption and non-adoption of green electricity by households. To reach this goal, we developed a theoretical framework rooted in cognitive science complemented with variables derived from economic theory. The resulting research model enabled us to formulate several hypotheses on the influence of variables related to the technical system, to individuals, and to economic issues concerning the adoption of green electricity by residents. These hypotheses were tested using a sample of Dutch households, some of which have adopted green electricity and some of which have not.

One of the most important empirical findings of our analyses is that the single block models, (i.e., models 1–3) are powerful but that combined models (models 4 and 5) are even more powerful, as was shown by the high levels of significance of the log-likelihood ratio tests. From a theoretical perspective, these empirical findings stress the relevance of combining theoretical

insights from different disciplines in adoption studies. The strength of combining different theoretical insights is also illustrated by the statistically significant variables in our estimations. First, adding intentional variables derived from economic theory to those derived from cognitive approaches was fruitful. A high level of perceived responsibility for the environment as well as a high willingness to pay increases the likelihood of adoption. Second, our findings also show that variables indicating intentions only provide a partial explanation for adoption. Including variables indicating actual (past) behaviour strengthened the explanatory power of our models further. Respondents who had higher levels of basic prior knowledge (which had to be acquired actively) and showed environmental friendly behaviour in the past (through membership of environmental associations) were more likely to adopt.

In this study, we tested 12 hypotheses. From an evaluation of our findings, it can be concluded that seven out of the 12 hypotheses were confirmed and coefficients had the expected signs. The overall picture is that early adopters of green electricity are persons who are knowledgeable about the use and background of sustainable energy and who often take a positive position on environmental and related issues, while the opposite is true for non-adopters. The lack of social and product visibility does not seem to bother early adopters. A high intrinsic motivation and the realisation of internal values may be explanations for this. Our findings that perceived relative advantages, the use of communication networks, and net disposable income are not of relevance to support this interpretation, because these stress the relatively autonomous position these early adopters take.

Finally, we would like to stress that one of the strengths of this research lies in the fact that the data were collected from adopters and non-adopters of green power just 1 month before the liberalisation of the Dutch green electricity market. As no massive information supply by (new) suppliers or the Dutch government was undertaken at that point in time, (mis-)perceptions of various aspects of green electricity played an important role in the decision-making process. The results of the research give a clear picture of what factors influence the early adoption of green electricity and what barriers must be removed to persuade the non-adopters to use green electricity. For the design of policy measures, variables that can be manipulated are of particular interest. Owing to the misperceptions of price level, ease of use and switching, and a lack of basic knowledge, a proper supply of information on these subjects is of crucial importance for the adoption of innovative products. A lack of knowledge of the consequences and the daily use of green electricity prevents residents from switching to green electricity.

As always, some caution is needed in assessing the contributions of our study. First, because comparable studies of the adoption of green electricity by residential users are scarce. Second, our population was relatively small, which might have some impact on our findings. Caution should also be exercised because one of the more important variables of this model, the level of basic knowledge, was not measured in a sophisticated way. The development of more sophisticated measures and the use of larger samples could be strategies for dealing with these problems in the near future. Third, an additional methodological limitation of this research should be noted. Those respondents who had purchased green power may now have reshaped their beliefs and may, therefore, have responded to our survey in such a way as to psychologically support their initial purchase decision. The effects of this kind of ex-post rationalisation can only be corrected by using a longitudinal research design in which beliefs and attitudes are measured before and after the decision of (non-)adoption. This was not possible within the scope of our research.

Acknowledgements

The authors wish to thank Jerry Hage (Centre for Innovation, University of Maryland, USA), Marius Meeus, Jan Faber (Department of Innovation Studies, Utrecht University), Koen Peters (Ameco Environmental Services, Utrecht), Jeroen Vermunt (Department of Methodology and Statistics, Tilburg University), Gerrit Rooks (Department of Technology and Innovation Policy, Eindhoven University of Technology), André Buys (Department of Engineering and Technology Management, University of Pretoria, South Africa) and the anonymous reviewers of this journal for their helpful comments. The usual disclaimers apply.

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